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Lake Winnipeg Walleye Fecundity.

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ABSTRACT

The fecundity of Lake Winnipeg walleyes was investigated from 76 and 72 gravid specimens collected in 1975 and 1981, respectively.

Fecundity was related to fork length and total weight for both years, and to age for 1981, using linear regression analysis on untransformed and full-log transformed data. Logarithmic transformations yielded higher correlation coefficients in all cases. Weight was a better predictor of fecundity than length. However, length should be used to relate fecundity to body size. The reasons for this are discussed. Fecundity-age relationships were not significant. Mean adjusted fecundities in 1975 were significantly higher than those in 1981 because fecundity was overestimated in 1975. Standard errors predicted from these regressions showed that 1981 fecundity estimates were more precise.

The regression equation that best describes the relationship between fecundity and body size is:

$$\log_e \text{fecundity} = -7.43 + 3.02 \log_e \text{fork length}$$

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INTRODUCTION

An analysis of fish fecundity in relation to other population statistics is essential for population dynamics studies, systematics in racial studies or in connection with total population estimates. Walleye fecundity is well documented for several lakes and rivers in Minnesota, Wisconsin, Michigan and Tennessee (Colby *et al.* 1979). Lake Erie populations were studied by Wolfert (1969). A controlled exploitation program on Savanne Lake is currently monitoring the effects on walleye fecundity (Baccante pers. comm.).

This project was carried out in 1981 to determine the number of eggs produced by Lake Winnipeg walleyes as a function of body size. In addition, fecundity data from a 1975 study were analyzed and compared to the results in 1981. This information is to be used to estimate recruitment in a Lake Winnipeg management model.

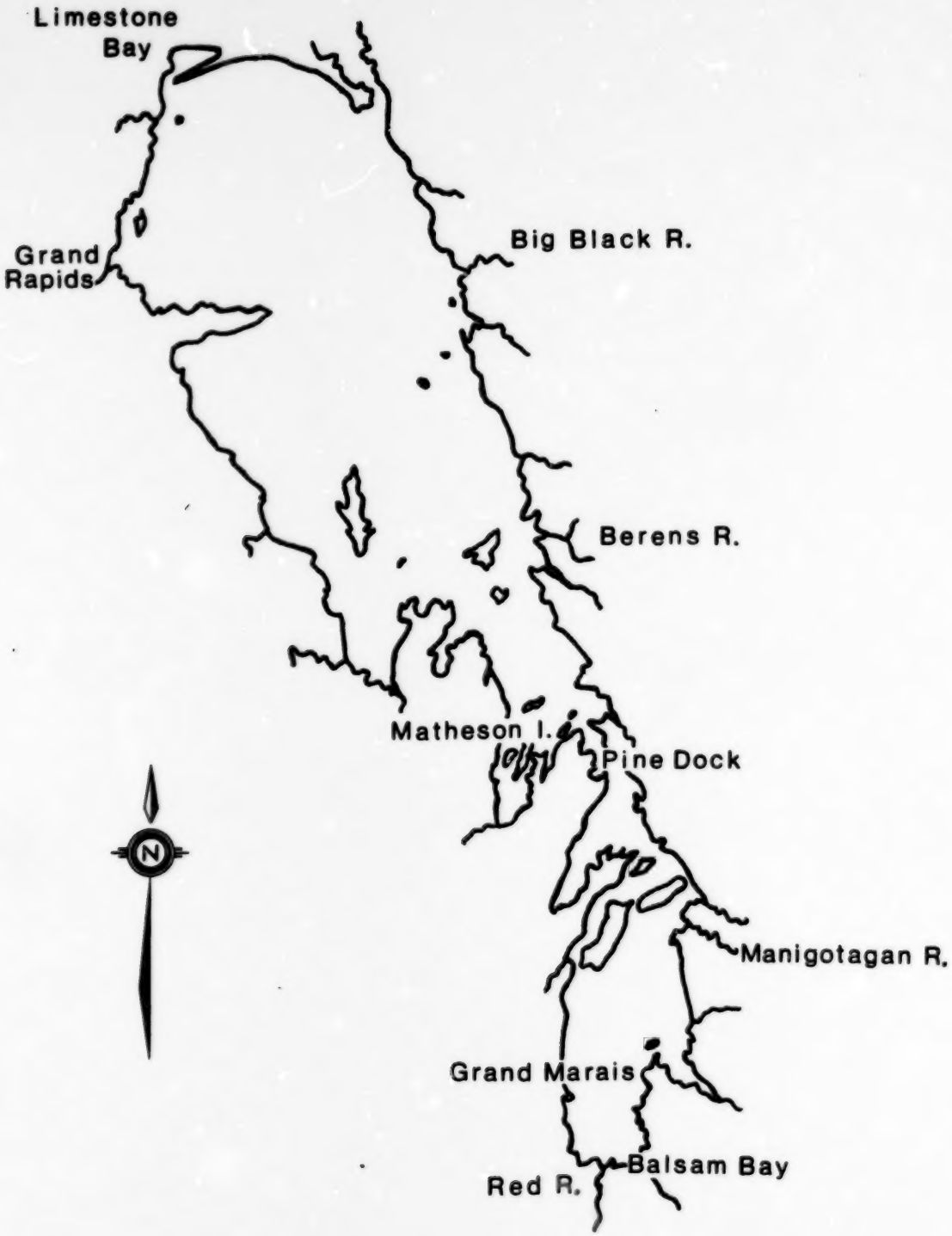

Fig. 1. Map of Lake Winnipeg showing sampling locations in 1975 and 1981.

METHODS AND MATERIALS

In 1975 and 1981, specimens of gravid females (Kesteven 1960) were netted in mouths of rivers or along the lake shore. Fecundity was estimated gravimetrically in 1975 and volumetrically in 1981.

1975

Walleyes were collected from gill nets or trap nets set in various locations from May 7 - 29 (Fig. 1, Table 1). Fish were processed as follows: Fork lengths were measured to the nearest 2 mm. Total weights were measured to the nearest 10 g on a Chatillon spring scale (Chatillon, Mississauga, Ontario). Six to ten scales were collected from the left side of each fish. Scales were removed below the lateral line and posterior to the origin of the pectoral fin. Both ovaries from each fish were carefully removed and stored in a 10% formalin solution for further analysis.

Before weighing, each pair of ovaries were washed in water to remove formalin and were air-dried to a constant weight. Left and right ovaries were weighed separately to the nearest 0.001 g on a Sartorius analytical balance. Three one-gram subsamples were taken from the anterior, median, and posterior portion of each ovary. The eggs from these six replicates were counted to obtain an average number of eggs per gram. The total number of eggs were estimated by direct proportion.

Table 1. Dates, locations and gear of capture of walleyes collected in Lake Winnipeg in 1975 and 1981.

Year	Date of capture	Location	Lake Area	Type of Gear (Mesh size in cm)	Number of fish
1975	May 7	Red R.	South Basin	Trap	1
	May 8-9	Manigotagan R.		GN (7.62, 8.89)	3
	May 12-16	Grand Marais		GN (7.62, 8.26)	8
	May 17-27	Matheson I.	Channel Area	GN (7.62, 8.26, 9.53)	12
	May 27	Pine Dock		GN (7.62)	1
	May 10	Grand Rapids	North Basin	GN (10.80)	1
	May 15-23	Berens R.		GN (9.53, 10.80)	14
	May 21-22	Big Black R.		GN (9.53)	3
	May 24-29	Limestone Bay		Trap	33
1981	May 7-9	Balsam Bay	South Basin	GN (7.62, 10.80)	116

The total number of eggs from three specimens were directly counted and compared to the estimated numbers of eggs to determine the % error.

1981

Walleyes were collected from gill nets set in Balsam Bay on May 7 - 9 (Fig. 1, Table 1). Fish were processed as follows: Fork lengths were measured to the nearest 2 mm. Total weights were measured to the nearest 5 g on a Detecto Matic spring scale (Detecto Scales Inc., Brooklyn, N.Y.). Both otoliths from each fish were removed and aged according to Erickson (1979). Ovaries were carefully removed and stored in Gilson's fluid (Bagenal 1968). After 3 - 5 weeks the egg-connective tissue mixtures were washed in water and transferred to 10% formalin.

Specimens were selected for fecundity estimates by randomly choosing five specimens from 10 mm length classes containing > five members and by choosing all specimens from 10 mm length classes containing $\leq$ five members.

Eggs were thoroughly cleaned as follows:

1. The preserved mixture was washed in water and large bits of connective tissue, fat, etc. were removed with forceps.
2. The mixture was transferred to a beaker and by repeated washing and decanting, most of the lighter bits of connective tissue could be poured off.

3. Eggs were liberated from bound connective tissue and cleaned further by vigorous stirring, washing and decanting.

4. Water was drained from the eggs and replaced with fresh 10% formalin.

Fecundity was estimated as follows:

1. The preserved eggs were poured into a graduated cylinder of suitable size. Repeated decanting and pipetting removed the surface layer of formalin.

2. The eggs were packed down and surface liquid was again removed. This process was repeated until a constant volume resulted.

3. Since a one-way analysis of variance showed a significant difference in the number of eggs/ml among specimens, three subsamples ranging from 1.0 - 2.0 mls were randomly chosen from each. Steps 1 and 2 were repeated to determine the subsample volumes.

4. The eggs from each subsample were counted to obtain an average number of eggs/ml. The total numbers of eggs were estimated by direct proportion.

Analyses

All statistical analyses were performed according to Snedecor and Cochran (1967).

Fecundity was correlated to age for 1981 data only, since

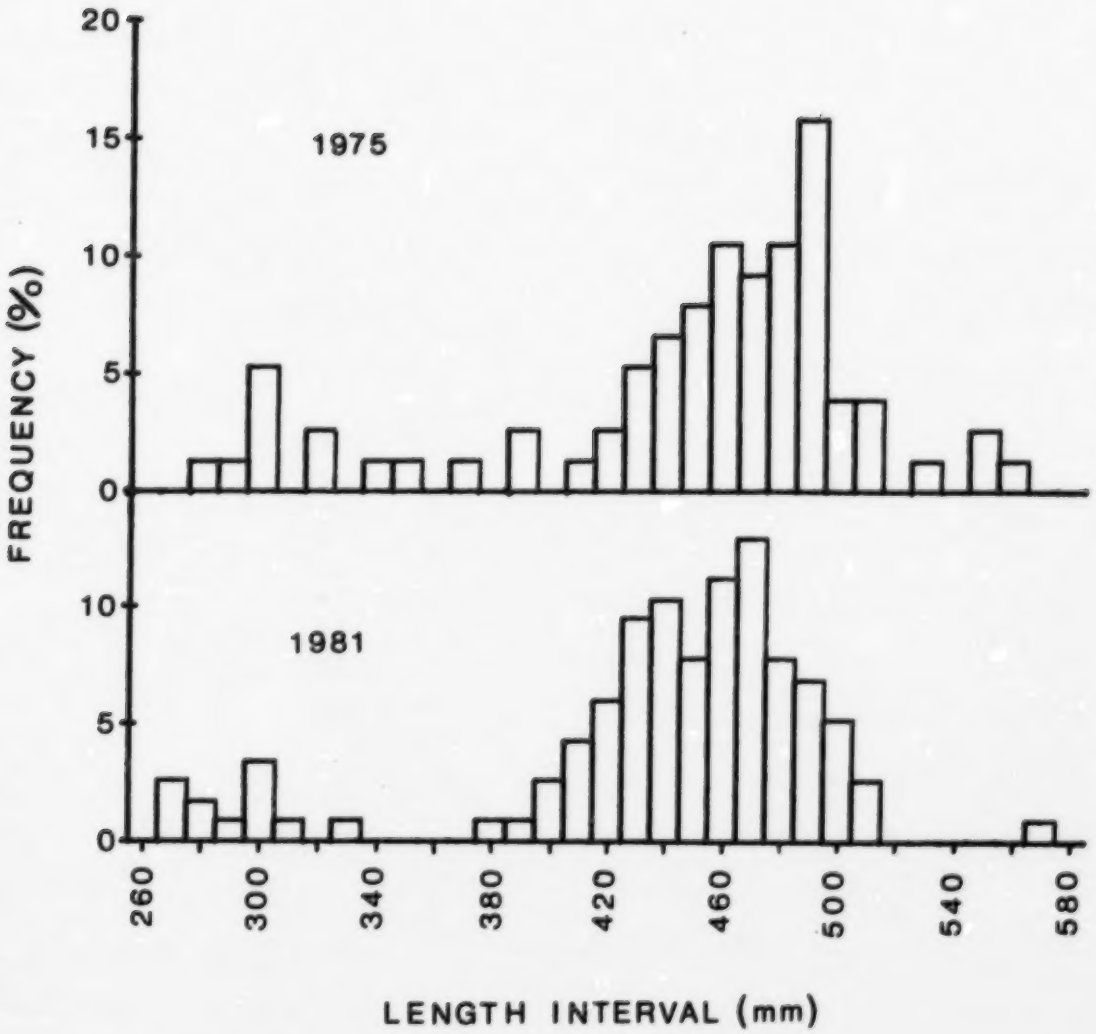

Fig. 2. Length-frequency distributions of samples of walleyes captured in Lake Winnipeg in 1975 and 1981.

otolith ages were not determined in 1975. Log-transformed size-specific fecundity curves from 1975 and 1981 were compared using analysis of covariance. Distributions of standard errors predicted from these regressions were used to compare the precision of 1975 and 1981 fecundity estimates.

RESULTS

Numbers of fish sampled in 1975 and 1981 were 76 and 116, respectively. Fecundity determinations were made on all specimens in 1975 and on 72 specimens in 1981. In 1975, 67, 17 and 16% of the fish were from the North basin, Channel area and South basin, respectively. All fish in 1981 were from one location in the South basin.

Length frequency distributions were bimodal in both years (Fig. 2).

Based on direct counts from three fish, 1975 fecundity was overestimated by 28.6 to 58.4%.

Regression equations determined from untransformed plots of fecundity versus lengths and weights determined in 1975 and 1981 were significant at $P = 0.05$ but were characterized by lower correlation coefficients than those of their log-log transformed counterparts (Figs. 3, 4, Tables 2, 3). Weight was a better predictor of fecundity than length in all cases. Correlation coefficients for length-specific and weight-specific fecundity curves were

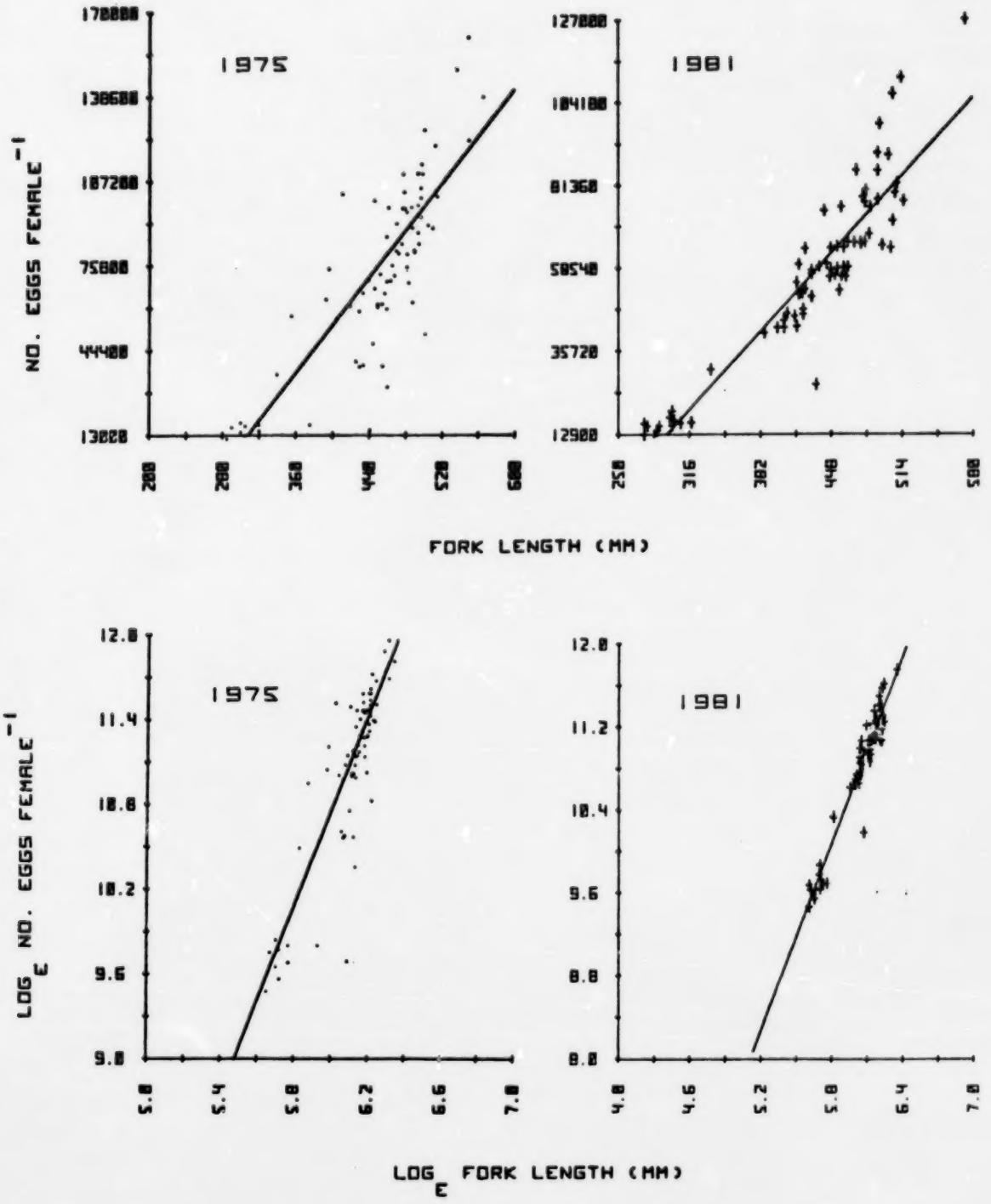

Fig. 3. Fecundity-length relationships of Lake Winnipeg walleyes in 1975 and 1981.

Table 2. Relationships between fecundity (F) and fork length (L) of Lake Winnipeg walleyes in 1975 and 1981.

Year	Linear Equation	Correlation coefficient	Test F ratio and d.f.
1975	$F = -121873.01 + 438.26\ L$	0.827	160.26 (1, 75)
	$\log_e F = -9.45 + 3.37 \log_e L$	0.870	230.38 (1, 75)
1981	$F = -82705.54 + 323.99\ L$	0.920	387.37 (1, 71)
	$\log_e F = -7.43 + 3.02 \log_e L$	0.964	931.11 (1, 71)

Table 3. Relationships between fecundity (F) and total weight (W) of Lake Winnipeg walleyes in 1975 and 1981.

Year	Linear Equation	Correlation coefficient	Test F ratio and d.f.
1975	$F = -3346.48 + 62.32\ W$	0.862	213.56 (1, 75)
	$\log_e F = 3.54 + 1.07 \log_e W$	0.881	257.45 (1, 75)
1981	$F = 1535.66 + 48.67\ W$	0.950	646.37 (1, 71)
	$\log_e F = 4.32 + 0.94 \log_e W$	0.966	982.57 (1, 71)

Table 4. Relationships between mean fecundities (F) and otolith age (A) of Lake Winnipeg walleyes in 1981.

Linear Equation	Correlation coefficient	Test F ratio and d.f.	Significance (P = 0.05)
$F = 64982.57 + -2169.86A$	0.220	0.20 (1,5)	non-significant
$F = -576.80 + 7916.20A$*	0.792	5.05 (1,4)	non-significant
$\log_e F = 8.87 + 1.04 \log_e A$*	0.813	5.86 (1,4)	non-significant

* excluding F at age 11

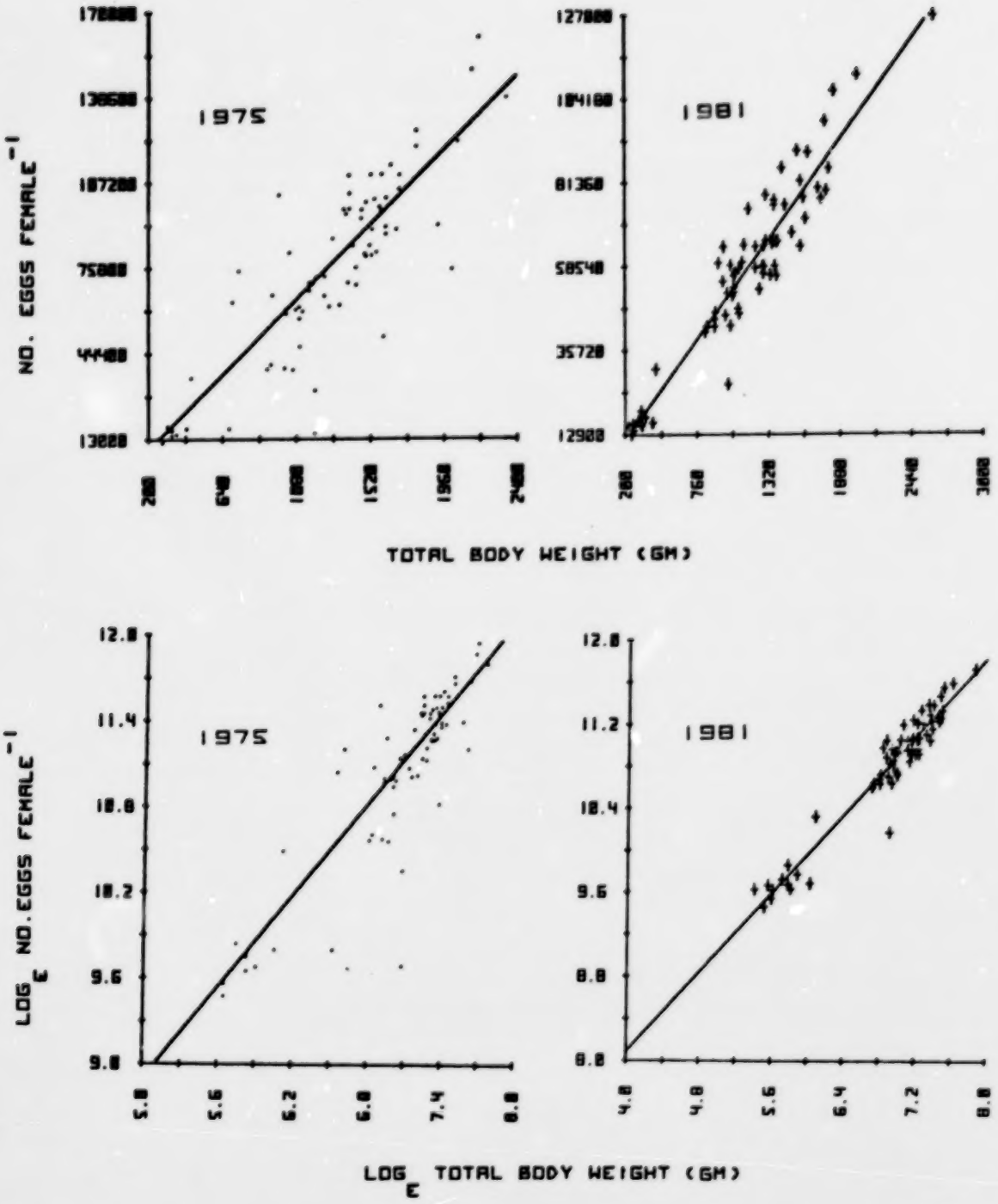

Fig. 4. Fecundity-weight relationships of Lake Winnipeg walleyes in 1975 and 1981.

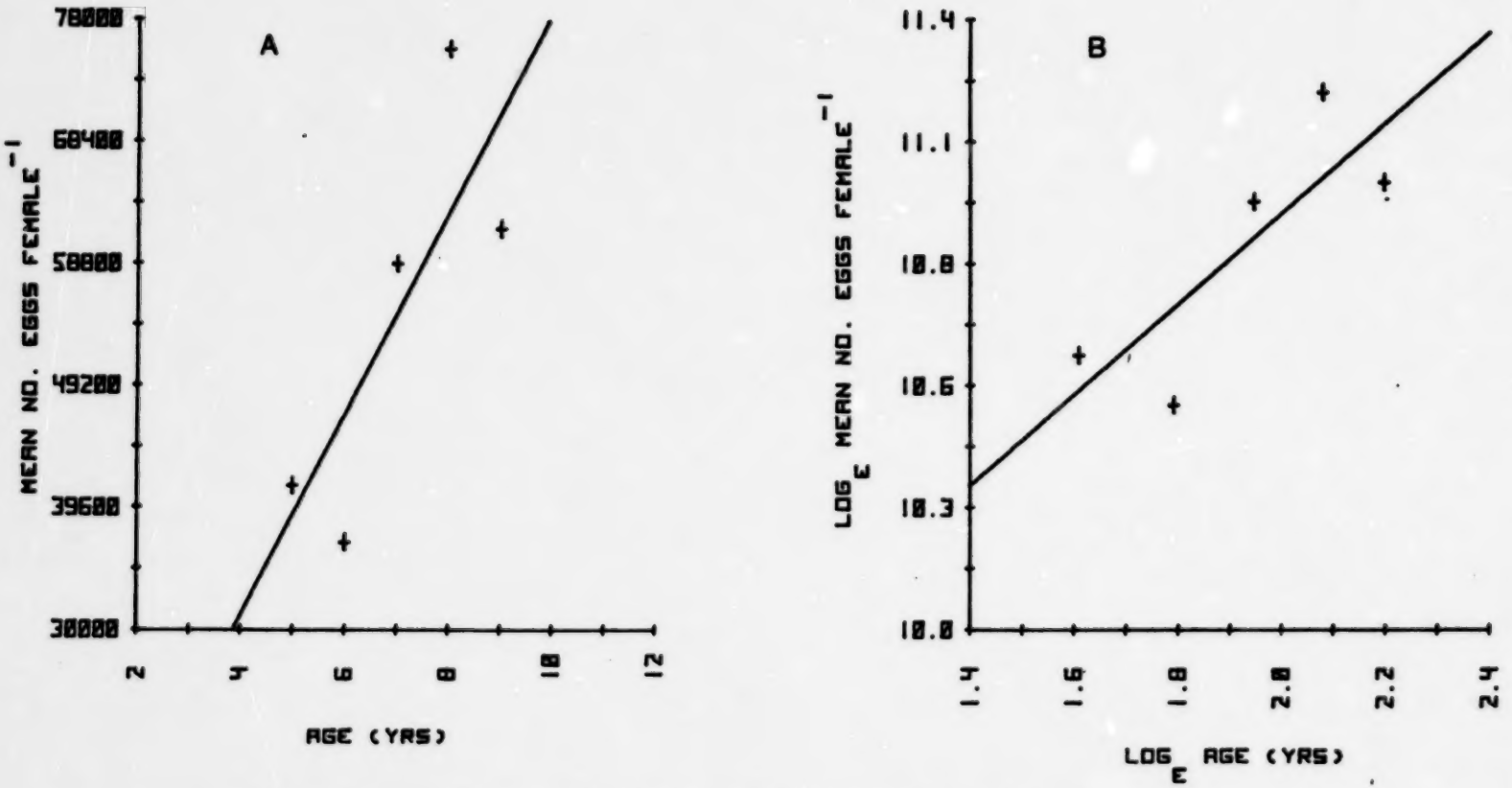

Fig. 5. Mean fecundity-age relationships of Lake Winnipeg walleyes in 1981.

A. untransformed
B. log-log transformed

Table 5. Results of covariance analysis of 1975 and 1981 fecundity-length and fecundity-weight relationships.

	Comparison	Slopes test F value and d.f.	Slope significance (P = 0.05)	Elevations test F value and d.f.	Elevation significance (P = 0.05)
1975	fecundity-length vs 1981 fecundity-length	2.180 (1, 144)	non-significant	7.532 (1, 145)	significant
1975	fecundity-weight vs 1981 fecundity-weight	3.345 (1, 144)	non-significant	10.647 (1, 145)	significant

greater in 1981 than in 1975. Linear equations describing these relationships indicate greater fecundity rates in 1975 than in 1981.

Regression analyses of untransformed (Fig. 5A) and full-log transformed (Fig. 5B) plots of mean fecundity and age did not reveal any significant relationships (Table 4).

Covariance analysis of full-log transformed plots of fecundity versus lengths and weights showed a significant difference between elevations but not between slopes (Table 5).

Standard errors predicted from regressions in figures 3 and 4 were 1.8 to 2.5 times greater in 1975 than in 1981 (Appendix A).

DISCUSSION

Length frequency distributions in 1975 and 1981 were bimodal due to mesh size selectivity and to the capture of slow growing individuals in the South basin. In 1981 only gill nets of 7.62 and 10.80 cm mesh size were used. Intermediate mesh sizes and trap nets used in 1975 captured fish in the 340, 350 and 370 mm length classes. In 1981, 10% of the sample was composed of slow growing individuals. Their age-specific mean lengths were 33 - 36% less than the age-specific mean lengths of the rest of the sample. This same trend was evident in 1975 but could not be quantified since scale ages tend to underage slow-growing walleyes (Erickson, 1979).

Weight was shown to be a better predictor of fecundity than length. This has been found in other fecundity studies on walleye

(Wolfert 1969, Baccante pers. comm.) on plaice (Pitt 1964, Bagenal 1966), on haddock (Hodder 1963) and on whitefish and lake trout (Healey 1978). Healey (1978) pointed out that when the ovary weights were included in a measurement of fish weight the relationships between fecundity and weight were autocorrelated. Bagenal (1966) preferred to relate fecundity to length in order to avoid temporal changes in the somatic condition factors.

Covariance analysis showed that the adjusted mean fecundities in 1975 were significantly higher than the adjusted mean fecundities in 1981. Since fecundity was overestimated by 28.6 to 58.4% in three specimens in 1975, it seemed likely that fecundity was at least slightly overestimated in all or most of the remaining specimens. The possibility that these differences were due to a change in fecundity between 1975 and 1981 or to differential fecundity between North basin and South basin populations could not be ruled out since both basins were sampled in 1975 whereas only one basin was sampled in 1981. Non-significant differences between the slopes of the 1975 and 1981 fecundity curves imply that the shapes of the curves are similar. Significant differences between the elevations of these curves imply that the 1981 fecundity curves are shifted towards smaller lengths and weights.

Gravimetric and volumetric methods have been evaluated by many workers on many different species (Bagenal 1968, Wolfert 1969, Eschmeyer 1950, Vladykov and Legendre 1940). In all cases, both methods were accurate to within 5%. In many cases they were accurate to within 1%. There was no tendency for either method to consistently overestimate or underestimate fecundity.

The mean number of eggs/kg has been used by many authors to compare the fecundity of walleyes from various lakes and rivers (Colby *et al.* 1979). These values range from 29,800 in Norris Reservoir, Tennessee, to 91,900 in Saginaw Bay, Lake Michigan. The mean number of eggs/kg determined for Lake Winnipeg walleyes in 1981 was 50,700. This value is nearly equivalent to that determined for walleyes from Lake of the Woods, Minnesota.

CONCLUSION

The determination of the number of eggs produced by Lake Winnipeg walleyes as a function of body size should be based on 1981 fecundity estimates and should preferably be based on the fecundity-length relationship. The regression equation describing this relationship is:

$$\log_e \text{fecundity} = -7.43 + 3.02 \log_e \text{fork length}$$

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Appendix A

Standard error values

Table A1. Standard error values predicted from regressions of log-log transformed plots of fecundity-length and fecundity-weight in 1975 and 1981.

Fecundity-length							Fecundity-weight						
1975			1981			Ratio of S.E.	1975			1981			Ratio of S.E.
X	$\hat{Y}$	S.E.	X	$\hat{Y}$	S.E.	1975:1981	X	$\hat{Y}$	S.E.	X	$\hat{Y}$	S.E.	1975:1981
5.6	9.40	0.232	5.6	9.46	0.096	2.42	5.4	9.32	0.229	5.2	9.22	0.108	2.12
5.8	10.08	0.150	5.8	10.06	0.061	2.46	6.0	9.97	0.155	5.8	9.78	0.075	2.07
6.0	10.75	0.083	6.0	10.67	0.037	2.24	6.6	10.61	0.090	6.4	10.34	0.046	1.96
6.2	11.43	0.083	6.2	11.27	0.046	1.80	7.1	11.15	0.068	6.9	10.82	0.034	2.00
6.4	12.10	0.150	6.4	11.87	0.077	1.95	7.6	11.68	0.100	7.4	11.29	0.045	2.22
6.6	12.77	0.232	6.6	12.48	0.113	2.05	8.2	12.33	0.167	8.0	11.85	0.074	2.26